Neural Network Hyperspectral Algorithms

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LONG-TERM GOAL

The long-term goal is to develop the scientific and computational basis for neural network-based algorithms for retrieval of inherent optical properties (IOP), water depth, and bottom type from hyperspectral imagery of coastal waters. These algorithms will capitalize on the power of neural networks and their associated "learning" algorithms to define complex nonlinear relationships between spectral radiance and water/bottom properties.

SCIENTIFIC OBJECTIVES

Neural network-based algorithms have been demonstrated for cases where the network is trained using ground truth from the site to which the resulting algorithm is applied (Sandidge and Holyer, 1998). The unanswered question is whether these relationships are universal, *i.e.*, can a neural network algorithm trained at one site be extended to retrieve accurate parameter estimates at other sites which were not included in the training. The scientific hypothesis to be tested is:

> "given a training set that includes many water, bottom, and atmospheric types, the training procedure will converge on those elements that are common to all members of the training set, namely, the physics of radiative transfer."

If the training procedure implicitly captures the physics, *i.e.*, if the hypothesis is true, then the neural network-based algorithms should tend to be universal.

APPROACH

To develop universal algorithms and to test the robustness of those algorithms when extended to new locations, it is necessary to generate a data set where many water, bottom, and atmospheric types are included. Cruise data coincident with overflights is, of course, the best way to produce such a data set. Existing data from COPE, CoBOP, HYMSMO, NAVO and LOE, and other programs will be utilized along with new collections supported under HyCODE. However, previous and ongoing field work cannot generate the entire data set. Therefore, field observations will be supplemented with modeled data using HYDROLIGHT for in water radiative transfer and MODTRAN for atmospheric radiative transfer. This hybrid training set will serve as the basis for the analysis conducted under this task.

Relationships between spectral radiance and the parameters of interest will be characterized. Neural models will be developed as the basis for remote sensing algorithms for the HRST sensor. The training process will be accomplished on a specially constructed hybrid neural network, which

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uses both stochastic and deterministic optimization techniques. The resulting algorithms will be characterized in terms of their expected performance and limitations.

WORK COMPLETED

Funding was received late in the year (July, 1998) so this project was active only during the 4th quarter of FY98. This project consists of startup activities in anticipation of expanded HyCODE efforts in FY99. The work accomplished was, therefore, directed at laying the foundations for the FY99 HyCODE project. Specific elements of work completed or underway are listed below.

1. Purchased upgrade to HYDROLIGHT version 4 and began modifications to this software for batch processing of many runs while stepping through ranges of various parameter values.

2. Began integration of HYDROLIGHT output with MODTRAN including batch runs of MODTRAN while stepping through ranges of various parameter values.

3. Completed hybrid neural network code which merges deterministic (gradient descent) and stochastic (simulated annealing) learning into a single procedure which accomplishes both speed of convergence and high probability of finding the global minimum.

4. Added error bound calculations of Welstead (1998) to hybrid learning algorithm to provide performance estimates for cases where the problem domain is not completely sampled in the training set.

5. Equipped NRL Code 7340 coastal research vessel (58 ft Hatteras) with kinematic bathymetry survey capability and with flow through system for AC9 and HYSTAR instruments.

6. Provided processed hyperspectral imagery and bathymetry data to Curt Davis (NRL-DC) for camparison of our neural network bathymetry results with those produced by the ORASIS system using beach and offshore endmember compositions.

7. NRL report "Bathymetry from Hyperpsectral Sensors: A Preliminary Analysis of the Problem" was completed and is presently in printing.

8. Conducted field work in the Mississippi Sound for a first validation of neural network-based IOP algorithms.

9. Ph.D. dissertation of Walt Smith, "Neural Network Solutions to the Ocean Optics Inverse Problem" has been completed in first draft form.

10. Conducted analysis of first data from the Hyperspectral Tethered Spectral Radiance Buoy leading to a poster paper for Ocean Optics XIV conference (Weidemann *et al.*, 1998b).

11. Conducted analysis of CASI multispectral data from Oceanside CA experiment leading to

conference paper (Weidemann *et al.*, 1998a). Received "best in session" award.

RESULTS

Validation studies for the neural network-based IOP algorithms resulted in good retrievals of scattering and absorption coefficients for Mississippi Sound waters which were not included in the training set. Figures 1 and 2 show typical results. IOPs measured at station 3 with the AC9 are compared to IOPs estimated by applying the neural network algorithm to spectral radiance data recorded by the ASD spectroradiometer. This is the first evidence that the hypothesis of universality my prove to be true with sufficient accuracy to lead to practical universal algorithms.
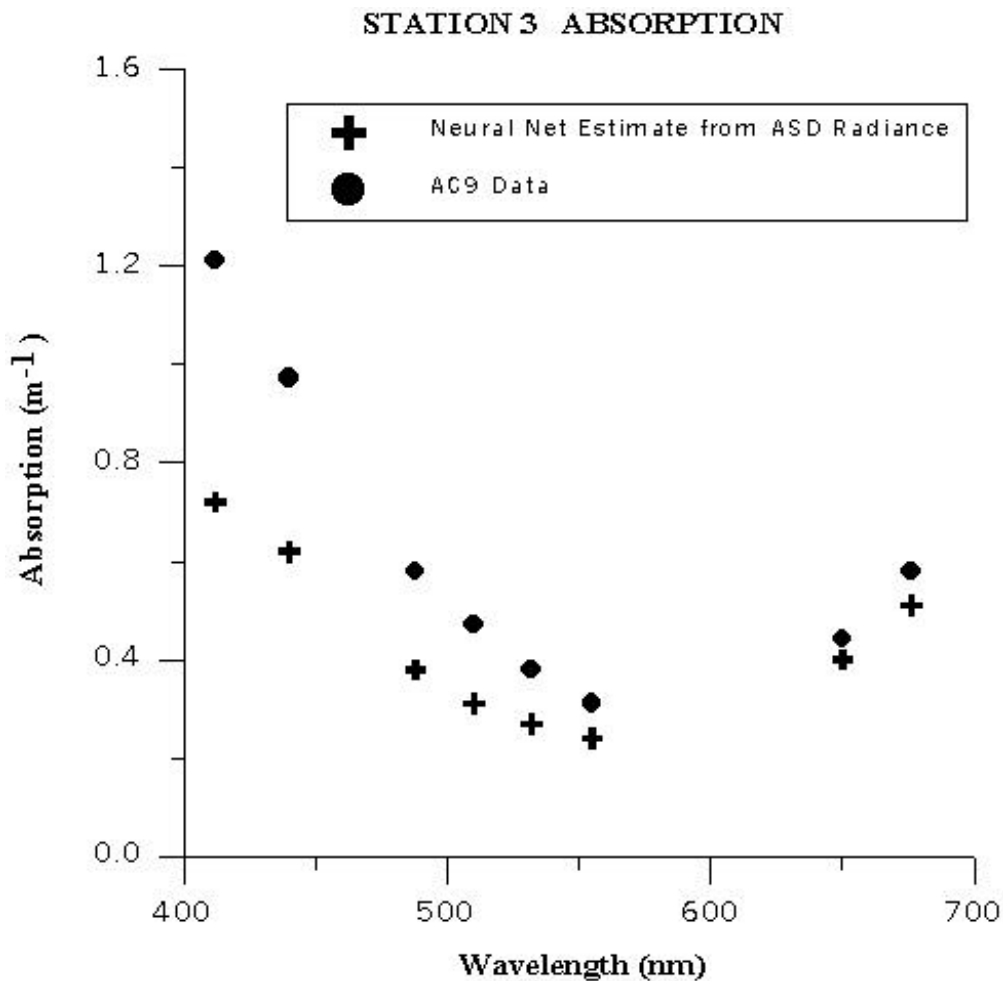

Figure 1 Absorption coefficients measured by the AC9 compared to
absorption coefficients estimated by the neural network algorithm using
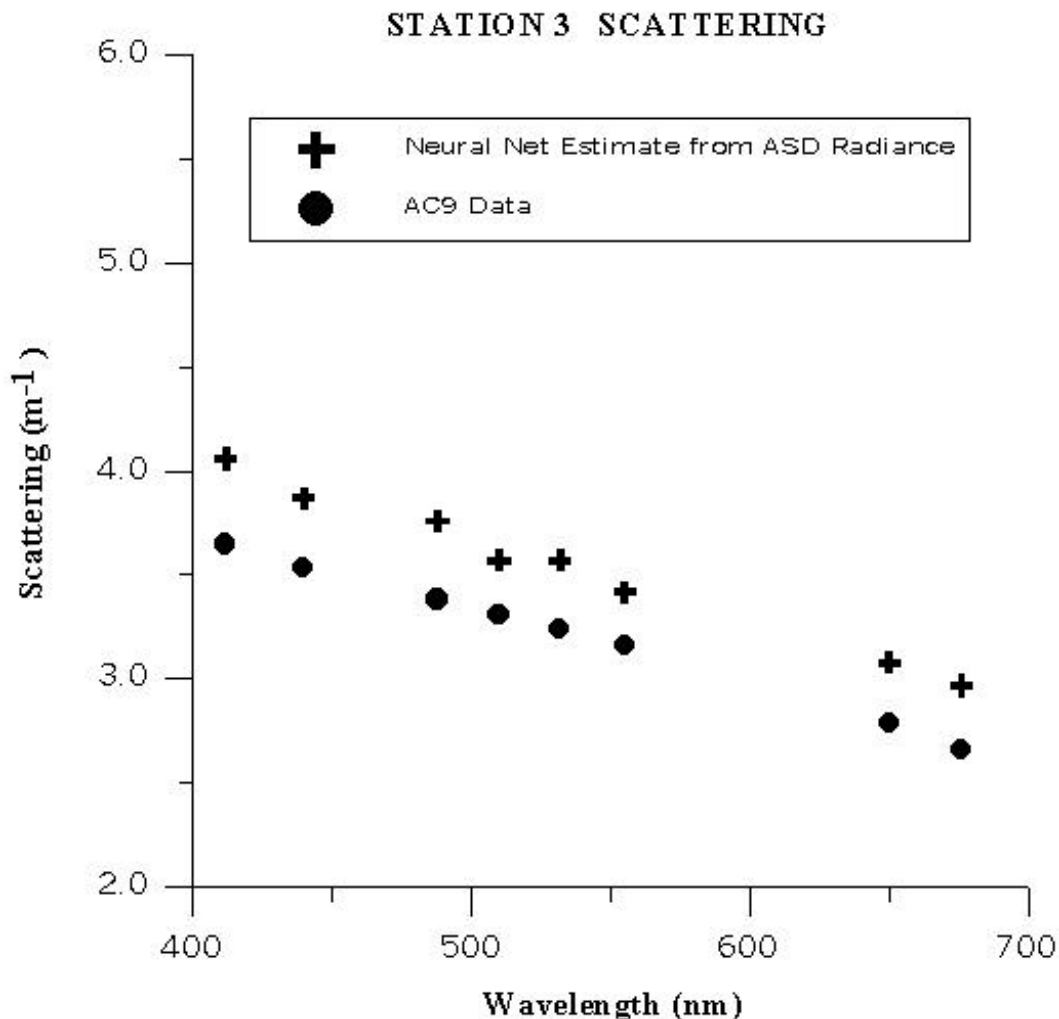*ASD observations of upwelling spectral radiance as input.*

Figure 2 Scattering coefficients measured by the AC9 compared to scattering coefficients estimated by the neural network algorithm using ASD observations of upwelling spectral radiance as input.

IMPACT/APPLICATIONS

Preliminary validation of the IOP algorithms was completed here. Preliminary validation of bathymetry algorithms was completed previously (Sandidge and Holyer, 1998). The implication of these preliminary findings is that neurocomputing approaches to hyperspectral algorithms for coastal ocean parameters should be continued. We feel that neural network-based algorithms may be the only way to retrieve certain parameters in the early stages of the NEMO mission.

TRANSITIONS

The Naval Oceanographic Office is interested in applying the neural network approach to bathymetry retrieval from LANDSAT imagery. We have entered into a joint study with NAVO, funded by NAIC, to evaluate the neural network approach and compare it with certain off-the-

shelf LANDSAT bathymetry algorithms.

RELATED PROJECTS

Our work is related to the NRL 6.2 Littoral Optical Environment project especially in the areas of methods for determining true dimensionality of hyperspectral data sets, and observation and characterization of internal waves in multispectral imagery.

It is interesting to note that certain operational algorithms for the Medium Resolution Imaging Spectrometer (MERIS) under development by ESA are based on neural networks, and are being developed following an approach similar to that proposed here (Doerffer and Shiller, 1997). Although there is presently no collaboration with these investigators, the MERIS is a closely related project and relationships will be pursued under the HyCODE project.

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